

USING DEFATTED MICROALGAE TO PRODUCE HEALTH VALUE ADDED EGGS

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INTRODUCTION

The consumers' demands for food products of superior health quality are growing (Hargis and Van Elswyk, 1993; Qi and Sim, 1998; Sim and Qi, 1995; Surai and Sparks, 2001). A number of studies have been conducted to fortify functional nutrients into animal origin foods such as meat, eggs, and milk through feed modifications (Cooper et al., 2004; Galobart et al., 2001; Hargis and Van Elswyk, 1993; Sim and Qi, 1995). Among these animal origin foods, eggs are considered the most convenient way to supply bioactive nutrients. Eggs are added into many foods for leavening, thickening, binding, and emulsifying (Stadelman, 1999). Eggs contain highly digestible proteins and have amino acid profiles similar to the human requirements. Eggs also supply various minerals and major vitamins (vitamins A, E, and B12) (Song and Kerver, 2000). However, regular eggs contain relatively high levels of omega-6 (n-6) fatty acids but low levels of omega-3 (n-3) fatty acids. Because these two types of fatty acids are metabolically and functionally distinct, and, in many cases, have opposite physiological effects, their balance in foods is considered to be an important factor (Simopoulos, 2000) associated with incidences of certain diseases (Shahidi and Wanasundara, 1998). Eggs also contain high amounts of cholesterol (185 mg/egg) that may negatively affect heart health at high intakes (Djousse and Gaziano, 2008). While protein and total lipid concentrations of eggs are not readily altered by diets of hens, fatty acid composition, mineral, and vitamin contents can be modified by feeding the hens with certain dietary ingredients.

Current n-3 Fatty Acids-enriched Eggs

The n-3 fatty acids often refer to a group of three polyunsaturated fatty acids: α -linolenic acid (ALA), eicosapentanoic acid (EPA), and docosahexanoic acid (DHA). These fatty acids are perceived to have beneficial effects on preventing or treating cancer (Sala-Vila and Calder, 2011), cardiovascular disease (Delgado-Lista et al., 2012; Kotwal et al., 2012), and inflammation (Ruggiero et al., 2009; Wall et al., 2010), and on cognitive developments (Perica and Delas, 2011; van de Rest et al., 2008). To produce n-3 fortified eggs, the simpler way is to feed hens with the ALA-enriched flaxseed or flaxseed oil. As ALA is a precursor of EPA and DHA, feeding the ALA-enriched ingredients may elevate the DHA concentrations in egg yolk (Ferrier et al., 1995; Van Elswyk, 1997b). However, the health benefit of the ALA enriched eggs is limited by the low conversion rate of ALA into EPA or DHA (less than 5%) in human (Brenna, 2002; Gerster, 1998). Flaxseed seems to be the first choice for producing the n-3 fortified eggs (Gonzalez-Esquerria and Leeson, 2000; Jia et al., 2008; Jiang et al., 1991), and a level of 10% supplementation effectively enhances the ALA and DHA contents in eggs (Scheideler and Froning, 1996). But, including >10% flaxseed in diets for hens showed negative effects on their egg production (Bean and Leeson, 2003; Leeson et al., 2000).

An alternate way to produce n-3 enriched eggs is a direct dietary inclusion of DHA and(or) EPA-rich fish meal or fish oil (menhaden, herring or tuna) (Leskanich and Noble, 1997). However, this approach may result in fishy tastes of the egg yolk (Ahn et al., 1995; Van Elswyk et al., 1992). In addition, polyunsaturated fatty acids are easily oxidized, and the n-3 fatty acids-fortified eggs may produce off-flavor (Caston et al., 1994; Van Elswyk et al., 1992). Thus, anti-oxidants are usually added in the hens' diets containing high flaxseed meal or other n-3 rich ingredients. However, even high levels of vitamin E supplementation could not totally prevent the formation of off-flavor in eggs from hens fed diets with flaxseed meal at >10% (Leeson et al., 1998). In production, flaxseed and menhaden oil are supplemented at < 5 and 1.5%, respectively, to avoid such problem.

Potential Roles of Microalgae in Animal Nutrition

Present food animal production is heavily dependent on corn-soybean meal based diets. Compared with other oil seed meals, soybean meal has high protein content and well balanced amino acid profile with high lysine content. While the global population is expected to reach 9 billion by the year 2050, the substantial use of soybean meal for animal production will compete against its needs for human consumption.

Many researchers around the world have attempted to find alternatives for soybean meal as the main source of feed protein. One of the alternatives is microalgae due to their high-quality nutrient profiles. Microalgae contain 8 – 71% crude protein, and their amino acid profiles are superior to those of many feed proteins (Becker, 2004). Microalgae also provide many vitamins (A, B1, B2, B3, B12, C, E, nicotinamid, biotin, folic acid, and pantothenic acid), pigments (β -carotene or astaxanthin), and polyunsaturated fatty acids (ALA, EPA, and DHA) (Spolaore et al., 2006). During the past, protein content has been a major factor to evaluate nutritional values of microalgae for animal production. At the present time, human health-beneficial nutrients or factors such as polyunsaturated fatty acids, β -carotene, and astaxanthin attract attentions for their potential in producing value-added foods.

Future Production of Value-added Eggs with Microalgae

As mentioned above, currently-available n-3 fatty acids-fortified eggs are mainly produced by dietary inclusion of flaxseeds. This strategy shows its limitation to reach >100 mg of DHA/egg due to the low conversion of ALA to DHA in hens (Van Elswyk, 1997a). As microalgae are original sources of EPA and DHA in the marine food chain, they may directly supply EPA and DHA into egg without a need for conversion. Abril et al. (1999) used dried microalgae to produce eggs containing 220 mg of DHA without lowering egg production yield. Herber and Van Elswyk (1996) fed hens with algae containing diets and produced eggs with elevated n-3 fatty acids and decreased n-6 fatty acids. Feeding hens with *Nannochloropsi* sp. enhanced egg concentrations of DHA and EPA, and egg yolk colors due to carotenoids content in the algae (Fredriksson et al., 2006; Nitsan et al., 1999). Our laboratory has conducted a series of experiments to assess effects of various types of microalgae, along with flaxseed oil, on fatty acid

profiles of eggs. We have found that microalgae as a source of n-3 fatty acids could alleviate side-effects of high flaxseed oil inclusion on the health of hens and elevate EPA content of eggs.

Carotenoids (β -carotene or astaxanthin) are lipid-soluble pigments that are primarily produced within phytoplankton, algae, and plants. Carotenoids are absorbed from animal diets and converted into various bioactive compounds that may have antioxidant activities and immunomodulation functions (Lorenz and Cysewski, 2000). The inclusion of 20% algae into hens' diets resulted in 4 times more carotenoids incorporated into eggs compared to the corn-soybean meal diet (Fredriksson et al., 2006). In addition, Astaxanthin from *Haematococcus* (microalgae) changed egg yolk color by 7 units of the Roche color fan (Lorenz and Cysewski, 2000).

SUMMARY

High protein contents and well-balanced amino acid profiles make microalgae a promising alternative protein source for soybean meal in animal production. Moreover, high n-3 fatty acid and pigment (β -carotene or astaxanthin) contents of microalgae offer unique health values. They could be used as protein and n-3 fatty acid sources to produce n-3 fatty acids, especially EPA and DHA, -enriched eggs. They may also be used to produce carotenoid- fortified eggs. Fortifying eggs with n-3 fatty acids and carotenoid together may enhance stability of eggs during storage and transportation.

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